MESOSCALE SIMULATIONS OF DYNAMIC FRAGMENTATION OF CERAMIC BARS

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Ceramic materials are finding increasing use in different advanced structural applications due to their better specific strength, thermal and chemical stability, wear resistance etc. In some of these applications, like turbine parts or armor protection, the ceramic components may encounter very high dynamic loads which often lead to failure and fragmentation of the material due to its brittle nature.

Considerable theoretical efforts have been directed towards the study of the fragmentation of brittle materials. Theories have been developed to predict the pattern of failure and the fragment size distribution of the failed specimen due to dynamic loading. But the assumptions involved in these theories are often quite restrictive. Moreover, most of these theories are developed for amorphous brittle materials and do not account for the granular microstructure of ceramic materials. In this work, the fragmentation process is studied at the mesoscale to account for the effect of the microstructure on the initiation and evolution of the fracture event. The analysis builds on recent cohesive zone modeling of fragmentation [1].

We study the fragmentation behavior of a ceramic bar subjected to a rapid expansion. An explicit cohesive volumetric finite element scheme is used to model the initiation, propagation and coalescence of multiple intergranular cracks, and the ultimate failure of the material in multiple fragments. A nonlinear kinematic description of the motion is used to account for the large rotations present in the fragmentation process. The granular microstructure of the ceramics is modeled with a mesh generation scheme that relies on Voronoi tessellation for the generation of the grains and inserts cohesive elements along the grain boundaries. An optimization-based contact enforcement algorithm is used to take into account the complex contact events taking place between numerous fragments with sharp corners. We investigate in detail the basic features of the fragmentation process such as its initiation time, its evolution, the extent of final damage, and the fragment size distribution. We present the effect of different parameters such as initial strain rate, average grain size and cohesive strength on these features, with a special emphasis on the statistical distribution of the fragment size during and after fragmentation.

References

[1] O. Miller, L. B. Freund, and A. Needleman, "Modeling and Simulation of Dynamic Fragmentation in Brittle Materials," *International Journal of Fracture*, v. 96, p. 101-125, 1999.